Journal of Neurology, Neurosurgery, and Psychiatry, 1977, **40**, 336–341

Idiopathic normal pressure hydrocephalus—a report of 73 patients

J. O. GREENBERG, H. A. SHENKIN, AND R. ADAM

From the Department of Neurology and Neurosurgery, Episcopal Hospital, Philadelphia, Pennsylvania, USA

SUMMARY In 1973 we reported results of ventricular shunting in 28 patients with idiopathic normal pressure hydrocephalus. The present report consists of a three year follow-up of the latter (series 1), and an additional 45 patients (series 2) are presented for further insight into the conclusions drawn from the original experiences.

Shenkin *et al.* (1973) reported on 28 patients with normal pressure hydrocephalus of unknown origin who had been treated by ventricular shunting, and concluded that the most predictable improvement occurred in patients who had markedly dilated ventricles, and whose outstanding symptom was disturbance of gait. However, other categories of patients with only dementia and moderately enlarged ventricles often showed remarkable, even if less predictable, improvement.

The progress of these same patients three years later is now reported with data on an additional, generally similar, group of 45 patients subsequently operated on, to provide further insight into the conclusions drawn from our original experience.

Patients and methods

Series 1 consists of the 28 patients previously reported by Shenkin *et al.* (1973) and now followed for an additional three years. The previous report was made on an average follow-up period of 9.7 months (ranging from five to 30 months). Series 2 consists of 45 patients subsequently operated upon and followed now for an average of 16.7 months (range three–29 months). The syndrome varies from mental changes alone to gait disturbance alone, with most patients in the two series having both features in varying proportions. As in the previous publication, the patients were placed in four categories (Table 1): dementia alone (category 1-D), principally dementia with some gait disturbance (category 2-D+a), gait disturbance with some dementia (category 3-A+d), and gait disturbance only (category 4-A). All patients were shown by objective criteria to have ventricular dilatation. The span across both lateral ventricles at the junction of the frontal horn and body was measured on a frontal radiographic projection, brow-up position (Taveras and Wood, 1964). Subjective observation by three separate examiners correlated well with the measured data. The following criteria were used for analysis of ventricular span: 40 mm or less, normal; 41–45 mm, mild enlargement; 46–55 mm, moderate enlargement; and more than 55 mm, severe enlargement. The percentage of patients in the ataxic groups in series 1 is distinctly greater than in series 2. This is significant when comparing overall results between the two series of patients and will be discussed below. In the combined series there were 40 females and 33 males.

Table 1 *Idiopathic normal pressure hydrocephalus—clinical categories*

	Series 1	*Series 2*
Category 1 (D)	7	12
	64.3%	75.6%
Category 2 (D+a)	11	22
Category 3 (A+d)	5	8
	35.7%	24.4%
Category 4 (A)	5	3
Total	28 patients	45 patients
Average age (yr)	68 (range 52–83)	69.5 (range 37–83)

Fifty-nine patients had fractional pneumoencephalography (PEG) preoperatively, and CSF pressure was measured in all: none were above normal levels. Postoperative PEG was carried out on 19 patients and the results have been reported by Shenkin *et al.* (1975). Computerised transaxial tomography (CT scan) was done on 10 patients pre and postoperatively, all in series 2. Ten additional patients in series 2 who had initial pneumoencephalograms had postoperative CT scans.

Address for reprint requests: Dr J. O. Greenberg, Episcopal Hospital, Lehigh Avenue and Front Street, Philadelphia, Pa. 19125, USA.

Accepted 10 November 1976

Radioactive cisternograms (Risa or Indium) were performed in 56 patients, technetium brain scans in all 73 patients, and electroencephalograms in 67 patients.

Ventricular fluid was shunted into the right atrium in nine patients (all in series 1) or the peritoneal cavity (64 patients). A low pressure Holter valve was used in 62 patients (85%) and a medium pressure valve in 11 (15%).

All patients were re-evaluated at regular intervals and final determination of the results was agreed to unanimously by all observers, including the patients' relatives. No improvement was graded as zero. Moderate improvement (Grade 1) was judged to have occurred when the patient became more independent in daily functions, regained continence, was able to communicate needs, feed himself, be left alone, and was better oriented. Patients who became totally independent and capable of resuming previous responsibilities were considered to be excellent results (Grade 2). The grading system was applied rigidly, and any doubt in evaluation of the patient was resolved arbitrarily by assignment to the next lower grade.

The severity of dementia alone was assessed in each patient of both series and classified as either mild, moderate, or severe. This was then used to compare series 2 with series 1 in regard to this parameter alone. The effect of the initial severity of the dementia on the results of shunting was also determined.

Table 2 *Outcome for patients in both series*

	Died	*Grade 0*	*Grade 1*	*Grade 2*	
Series 1 (28 cases—four deaths)					
Category 1		5	1	1	
			28.5%		44.4%
Category 2	4	1	3	3	
			54.5%		
Category 3		0	1	4	
			100%		100%
Category 4		0	1	4	
			100%		
Totals	4	6	6	12	
			64.3%		
Series 2 (45 cases—one death)					
Category 1	1	10	1	1	
			16.7%		26.4%
Category 2		15	2	5	
			31.8%		
Category 3		4	2	2	
			50%		54.5%
Category 4		1	1	1	
			66.7%		
Totals	1	30	6	9	
			33.3%		

Results

At the time of our initial evaluation, averaging 9.7 months after operation, 12 patients in series 1 had excellent results (Grade 2), six showed moderate improvement (Grade 1), six were failures, and there were four postoperative deaths (Table 2). Thus 64.3% of the patients initially responded to treatment. A further three year follow-up revealed that six of the successfully treated patients had deteriorated. This leaves a success rate of 42.8% at almost three years after shunting.

We reviewed the six patients from series 1 who were considered to have been successfully treated initially but were found to be failures at follow-up. All six of these patients at the time of the initial report were considered Grade 1, or moderately improved. There were three males and three females. The age range was between 62 and 78 years with a mean of 68.5 years. Preoperative duration of symptoms in this group ranged from six to 120 months with a mean of 43 months. Five of the six patients were in either categories 1 or 2 (primarily demented), and only one patient was in category 3. The patient in category 3 had a severe dementia as well as severe ataxia. Two patients had associated Parkinson's disease, one was an alcoholic, and one had cerebral vascular disease. Five of the six had moderate dementia and one was severely demented. Of the five electroencephalograms done on these patients, all were grossly abnormal. The ventricles were only moderately enlarged in all six. The risa cisternogram was normal in three patients, doubtful in two, and positive in only one. Spinal fluid protein ranged from a low of 0.32 g/l to a high of 0.85 g/l with a mean of 0.493 g/l. Only one of these patients had an elevated spinal fluid protein. There were four ventriculojugular shunts. Three medium pressure and three low pressure valves were installed. The duration of improvement in this category of patients ranged from two to six months with a mean of 3.3 months. Two of these six patients are dead, and four are alive and doing poorly.

In series 2, at an average of 16.7 months after shunting, nine patients have had excellent results (Grade 2), six are moderately improved (Grade 1), and 30 were failures (Grade 0). Thus only 33.3% responded to treatment. Combining the two series gave an overall improvement of 45.2% (33/73), but in prolonged follow-up the yield is 37% (27/73).

Table 2 also outlines the results in each series cor-

related with the presenting clinical picture. It is still evident that patients with gait disorder as the primary symptom do better than those with primarily dementia, but the results in series 2 overall are less favourable than originally reported in the first series. This will be discussed below.

Incontinence was overcome in nine of 22 patients (40.8%) in both series.

Considering dementia alone, series 2 patients as a group were more severely demented than those in series 1. It was considered that 68.8% of patients in series 2 were severely demented as compared with only 10.7% of such patients in series 1. One-third of patients in series 1 were mildly demented whereas no patients were so classified in series 2. This is of great significance in comparing results in our two series since it was also noted that, overall, 38% of mildly demented patients improve after shunting as compared with 33.3% of the moderately, and only 24.2% of the severely demented.

The duration of symptoms in relation to outcome is given in Table 3, and refutes our previous observation (Shenkin *et al.*, 1973) that patients with shorter duration of symptoms do worse. The improvement rate in the shorter duration group was almost the same as in the longer duration group. Of the 33 improved cases (Grades 1 and 2), in both series, 19 improved within one month, 10 improved in one to three months, and only four patients improved after three months. The severity of symptoms did not affect the rapidity of onset of improvement.

Table 3 *Duration of symptoms in relation to outcome*

Duration (mo)	*Patients*	*% improved*	
Less than 12	16/30	53.3	53.3
12–23	6/21	28.5	
24–35	3/6	50	51.5
36–60	5/9	55.5	
60	3/12	25	

In series 1, when originally reported, nine out of 28 patients (32%) had died. In series 2, 13 out of 45 patients (28%) have died. Following series 1 for another three years revealed that seven more had died. Thus, in the entire series of 73 patients, 42 are still alive (two lost to follow-up); 21 of these are Grade 0, seven are Grade 1, and 14 are Grade 2. Combining Grades 1 and 2 reveals that 21 of the 42 live patients (50%) were treated successfully. Of the 29 dead patients in the entire group, 24 died of causes unrelated to the shunt, months to years postoperatively. In this group, 19 patients were Grade 0, none were Grade 1 and five were Grade 2 at the time of their deaths. Thus only 20.8% of the patients who died were successfully treated before death. The average age of the surviving patients was 68.0 years, and the average age for the non-survivors was 70.3 years.

In the group as a whole there were 43 patients aged 70 years or less, of whom 16 were successfully treated (37.2%). In the age range 71–75 years, eight of 21 (38%) improved: two of seven (29%) patients aged 76 to 80 years improved, and there was only one patient over 80 (age 83) years who was shunted with an excellent response.

LABORATORY STUDIES

Isotope brain scans were normal in all 73 cases. Isotope cisternograms were done in 56 patients. It was considered abnormal when there was early ventricular filling and no ascent of isotope over the convexities in 72 hours. Ten patients with normal cisternograms improved, and 10 were failures. Three patients with questionable abnormal cisternograms (images not clear enough to be certain of persistent activity at 24 hours) improved while 11 did not. Eleven patients with abnormal cisternograms were successfully treated, and eleven failed.

Twenty-five percent (three out of twelve) of patients with mild ventricular enlargement, 31% (12 out of 39) with moderate enlargement, and 57% (12 out of 21) with severe enlargement were treated successfully.

Ten patients in the entire series had significantly elevated CSF protein (greater than 0.6 g/l—highest 1.0 g/l), and six of these patients improved.

Brown and Goldensohn (1973) report that 54.5% of 11 patients with normal pressure hydrocephalus had normal electroencephalograms (EEG). Our experience in the 67 patients who had EEG was quite different; only six of 67 (8.9%) were normal. A variety of non-specific abnormalities (focal, diffuse, and bilateral) were seen. Interestingly, even six of 18 patients with no background alpha rhythm improved. Wood *et al.* (1974) confirmed the high incidence of abnormal EEG, and indeed Messert and Wannamaker (1974) state that a normal EEG indicates a poor response to shunting. In six of our patients with a normal EEG, three were treated successfully.

Ten patients had preoperative CT scans. Six were successfully treated, and all six demonstrated severe ventricular enlargement. Two patients with moderate cerebral atrophy on the CT scan, and one with mild atrophy as reflected in prominence of cortical sulci, responded to shunts.

COMPLICATIONS

Five patients (6.9%) died within one month of surgery, or as a direct result of surgery. Four were in series 1. One patient died one day after operation, of a myocardial infarction. One patient developed pneu-

monia and died four days postoperatively. Two patients died one month after operation, one of a perforated duodenal ulcer, and one of a pulmonary embolus and uraemia. One patient in series 2 had an immediate postoperative hemiplegia with stupor, and died three months later. Udvarhelyi *et al.* (1975) reported a 9% surgical mortality.

Two patients in series 1 developed typical intracranial hypotensive headaches, In one, the low pressure valve was replaced by a valve of medium pressure with remission of headaches, and in the other, the valve had to be removed before headaches remitted. There were two infected shunts (two and three months postoperatively), and two disconnected or blocked shunts (five months and four years postoperatively). In series 2 there were 10 shunt related complications. In seven subjects the ventricular end blocked; most occurred before 10 weeks. In one case the peritoneal end disconnected in two weeks. There were two infected shunts (one and 14 months postoperatively). There were two subdural haematomas (one bilateral diagnosed at 11 weeks—and one with small bilateral haematomas diagnosed at seven weeks) for a total incidence of 2.7%. One patient in series 2 had shunt related headaches which cleared spontaneously. One patient had a postoperative hemiparesis which remained unimproved. One patient had postoperative seizures controlled with anticonvulsants, and one patient had a pulmonary embolus and recovered. There was only one surgical death in series 2. The two series combined produced a morbidity rate of 32.8% (24 of 73 patients), and a total complication rate of 39.7% (29 of 73 patients).

ASSOCIATED DISEASES

In series 1, one of four patients with Parkinson's disease improved as compared to one of six in series 2. None of the six epileptics in the combined series improved. Three of four alcoholics in series 1 and one of three in series 2 improved. All alcoholics were first treated for six weeks with alcohol abstinence, diet, and vitamins with no clinical change before surgery. Before normal pressure hydrocephalus became recognised, all of these patients would have been institutionalised. Seven of 16 patients in group 1 with pyramidal tract signs improved while one of 10 in series 2 improved.

Discussion

Experience with 45 further patients operated upon for a presumed idiopathic type of normal pressure hydrocephalus confirms our original conclusion that patients with either predominantly gait disturbance or markedly dilated ventricles respond best to ventricular shunting. Indeed, if these two factors occur in combination, a favourable result is almost predictable (83.3%). Furthermore, extended follow-up of our original series of 28 patients indicates that, if these criteria are present, the favourable result is more likely to persist. Only one (10%) of the predominantly ataxic group (categories 3 and 4) deteriorated after an initial favourable result, while of the predominantly demented group (categories 1 and 2) who initially improved, five (62.5%) deteriorated. Moreover, none of these six patients of series 1 whose improvement was not maintained beyond a year had more than moderately dilated ventricles, all of which were made smaller by shunting (Shenkin *et al.*, 1975). None of these patients were better than grade 1 as far as improvement was concerned. This seems to indicate that patients whose improvement is not maintained have degenerative brain disease with dementia (Alzheimer's?), aggravated by a degree of hydrocephalus that could be the result of changes in brain elasticity or obstruction, the relief of which gave only temporary improvement, and thereafter degenerative brain disease progressed relentlessly. Coblentz *et al.* (1973) have also suggested that a degree of hydrocephalus may complicate a degenerative brain disease.

It has seemed reasonable to all observers that shunting operates by ventricular decompression and, therefore, the objective of all testing has been to distinguish in these generally elderly patients between those whose symptoms are due to a process interfering with cerebral spinal fluid circulation (a hydraulic effect), and those whose problem is cerebral degeneration. Reasoning from our results and along these lines, it might be said that gait disturbance, which responds well to shunting, is produced by a hydraulic effect, and that dementia is the result of brain degeneration since these patients react less well to shunting. That some primarily demented patients do improve (and the ones with the largest ventricles do best) could indicate that brain degeneration has an associated hydraulic effect in some instances. Therefore, it would still be valid to attempt to discern, in these patients preoperatively, when this hydraulic change is present.

We analysed our results to see if we could correlate the largest ventricles with ataxia and excellent results which would demonstrate a hydraulic process, and smaller ventricles with dementia and failure of shunting, identifying a degenerative disease. However, we could find no more correlation between severe ventricular dilatation and ataxia than with dementia. Forty of 48 patients in categories 1 and 2, and 20 of 24 patients in categories 3 and 4 had moderate to severe ventricular enlargement. Moreover, there are sufficient exceptions in all directions to cast doubt that any formulation explains all cases.

The fact that our therapeutic effort uses a hydraulic system that is not always predictable may further obscure any correlation of results with initial disease processes. We have learned from experience that, if we install a low pressure valve which closes at a pressure of 20 mm of water *in vitro* this might not actually occur *in vivo*. On three occasions in recent patients of series 2 we changed valves, obtaining lower intraventricular pressures as determined by tapping the Rickham reservoir in the supine position, and have improved the patient either *de novo* (one patient), or to a previously improved state (two patients). It appears necessary to have 0–10 mm of water pressure at the Rickham reservoir in the supine position to be certain that intracranial pressure has been effectively lowered by shunting. This has only recently been determined, and it may be that if we had routinely tested our patients in this way in the past, even more would have been improved by proper decompression.

The striking discrepancy found in comparing the two series of patients is the fact that in the first group of 28 patients, we reported a 64.3% improvement rate and in the second, more recent, series of 45 patients, only 33% improved. However, closer analysis reveals that the patient population of series 2 was unintentionally different from series 1 and this, we believe, was the reason for the decrease in positive yield. In series 2, the degree of dementia was greater (64% in categories 1 and 2 versus 51.8%), and the amount of ataxia was less (36% in categories 3 and 4 versus 48.2%). The ventricular sizes overall in series 2 tended to be somewhat smaller than series 1. We believe this came about because when the knowledge of our interest in this subject spread, the referral of patients to us tended to be biased towards patients from the vast pool of senile dementias in our population compared with the general run of neurological material originally available in which the proportion of ataxic patients was greater. The discrepancy between the percentage of positive yields in the two series against the background of the difference in characteristics of the two series is an internal check on the validity of our observations on individual patients, their clinical course, and original conclusions. The difference in improvement rate between those patients that have died and those that have survived (20.8% versus 50%) over the period of observation suggests that the non-survivors may have had a progressive disorder of the central nervous system and/or other organ systems not amenable to shunting, and further confirms the reliability of our criteria for improvement.

It is still of prime importance to determine which patients with ataxia and dementia and a degree of presumed normal pressure hydrocephalus will or will not respond to shunting. Originally we concluded, and it has since been confirmed by others (Wood *et al.*, 1974), that no single or group of tests will make this determination. Further experience with series 2 confirms this conclusion. Other observers have done brain biopsies in an effort to pick proper candidates for shunting, and have failed (Coblentz *et al.*, 1973). At this time only the clinical picture together with the degree of ventricular dilatation present can be of any predictive value as to the results of shunting. There is no way of being certain of the result in any specific case.

Several added points of interest have emerged from the study of this larger series of patients. In the first place, there is no correlation between the results obtained and the duration of symptoms before surgery (Table 3). Originally we reported that the shorter the history, the worse the results. The opposite was stated by others with a smaller experience (Jacobs *et al.*, 1976). From our larger experience, no such correlation emerged. Another point of interest is that the age of the patient was not of consequence; patients over 70 years of age did as well as younger patients.

Comparing our results with others (Table 4) reveals a higher success rate in some studies. It may be that longer follow-up in these studies would demonstrate deterioration in some patients.

Table 4 *Summary of results of series of patients shunted for normal pressure hydrocephalus*

Series	*Cases*	*Number improved*	*% improved*
Ojemann *et al.* (1969)	28	18	64
Udvarhelyi *et al.* (1975)	55	33	60
Salmon (1972)	80	21	26
Present study	73	27	37

With regard to the complications of surgery, the morbidity of 32.8% represents for the most part reparable difficulties with the shunting apparatus. This complication rate is somewhat less than that of Udvarhelyi *et al.* (1975) (44%). Our infection rate was 5.6% compared to 18% in that series. We looked carefully for subdural haematomas (including postoperative angiograms), and only 2 (2.7%) were found. This compares favourably with other reports of 4% (Udvarhelyi *et al.*, 1975) and 23% (McCullough and Fox, 1974).

With regard to postoperative mortality, there were four deaths in series 1 and one in series 2. In retrospect, one patient in series 1, although neurologically a good candidate for shunting, was too ill and probably should not have been operated upon. Why the not uncommon fatal complications occurred in

the first series of 28 patients but not in the second series of 45, is not explicable.

The CT scan could be a major development in this area. This noninvasive, safe procedure gives as much pertinent information regarding ventricular size as the PEG. Follow-up changes in ventricular size can be studied easily. Sulcal atrophy is readily seen on the CT scan and much to our surprise did not seem to impair results in a few cases. This has been remarked upon by others (Le May and New, 1970; Wood *et al.*, 1974).

References

Brown, D. G., and Goldensohn, E. S. (1973). The electroencephalogram in normal pressure hydrocephalus. *Archives of Neurology (Chicago)*, **29,** 70–71.

Coblentz, J. M., Mattis, S., Zingesser, L. H., Kasoff, S. S., Wisniewski, H. M., and Katzman, R. (1973). Presenile dementia. *Archives of Neurology (Chicago)*, **29,** 299–308.

Jacobs, L., Conti, D., Kinkel, W. R., and Manning, J. (1976). Normal pressure hydrocephalus. Relationship of clinical and radiographic findings to improvement following shunt surgery. *Journal of the American Medical Association*, **235,** 510–512.

LeMay, M., and New, P. F. J. (1970). Radiological diagnosis of occult normal pressure hydrocephalus. *Radiology*, **96,** 347–358.

McCullough, D. C., and Fox, J. L. (1974). Negative intracranial pressure hydrocephalus in adults with shunts and its relationship to the production of subdural hematoma. *Journal of Neurosurgery*, **40,** 372–375.

Messert, B., and Wannamaker, B. B. (1974). Reappraisal of the adult occult hydrocephalus syndrome. *Neurology (Minneap.)*, **24,** 224–230.

Ojemann, R. G., Fisher, L. M., Adams, R. D., Sweet, W. H., and New, P. F. J. (1969). Further experience with syndrome of normal pressure hydrocephalus. *Journal of Neurosurgery*, **31,** 279–294.

Salmon, J. H. (1972). Adult hydrocephalus: Evaluation of shunt therapy in 80 patients. *Journal of Neurosurgery*, **37,** 423–428.

Shenkin, H. A., Greenberg, J., Bouzarth, W. F., Gutterman, P., and Morales, J. O. (1973). Ventricular shunting for relief of senile symptoms. *Journal of the American Medical Association*, **225,** 1486–1489.

Shenkin, H. A., Greenberg, J. O., and Grossman, C. B. (1975). Ventricular size after shunting for idiopathic normal pressure hydrocephalus. *Journal of Neurology, Neurosurgery, and Psychiatry*, **38,** 833–837.

Taveras, J. M., and Wood, E. H. (1964). *Diagnostic Radiology*. p. 284. Williams and Wilkins: Baltimore.

Udvarhelyi, G. B., Wood, J. H., James, A. E., and Bartlet, D. (1975). Results and complications in 55 shunted patients with normal pressure hydrocephalus. *Surgical Neurology*, **3,** 271–275.

Wood, J. H., Bartlet, D., James, A. E., and Udvarhelyi, G. B. (1974). Normal pressure hydrocephalus: diagnosis and patient selection for shunt surgery. *Neurology (Minneap.)*, **24,** 517–526.